The Development of the Atomic Model (I)

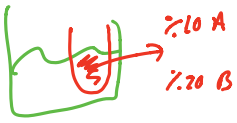
Democritus (5th century B.C.)

- Greek philosopher that hypothesised that all matter is made of very small and indivisible particles, which he called "atomos".

John Dalton (1808)

- Developed the concept of an atom with greater detail than that of Democritus
- Dalton's atomic theory can be summarized as follows:
  - All elements are composed of tiny indivisible particles called atoms.
  - Atoms of one element are identical, but different from all other elements.
  - Atoms of different elements combine in whole number ratio to form compounds.
  - A chemical reaction is the rearrangement of atoms (atoms are neither created nor destroyed).
- Dalton proposed a "solid ball" model of the atom.
- His atomic theory explained three laws that were known at the time:

1. The Law of Conservation of Mass (Lavoisier - 1789)
   - *Mass can neither be* created *nor* destroyed.
2. The Law of Definite Proportions (Proust - 1799)
   - *The proportions of elements by mass remain* constant *in different samples of the same compound.*



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3. The Law of Multiple Proportions (Dalton)
   - *When atoms can react together to form* different *elements, the masses of the second element combined with the first element of a constant mass will result in a ratio of small whole numbers.*

Ex:
CO: 100g of C and 133g of O: $\frac{133\text{g of O}}{1\text{g of C}}$
CO_2: 100g of C and 266g of O: $\frac{2.66\text{g of O}}{1\text{g of C}}$
1.33 : 2.66 or 1 : 2

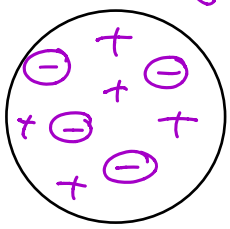
- Some drawbacks of the Dalton's atomic theory:
  1. Atoms are not divisible
  2. Isotopes → Same elements can have the same mass.

J.J. Thomson (1897)

- Studied electric currents in gas discharge tubes, particularly cathode ray tubes.
- Cathode ray tubes:
  - A glass tube in which most of the air is removed.
  - They emit rays, called cathode rays, which are normally invisible, but when they collide with the remaining gas molecules in the tube the rays become visible.
- Noticed that cathode rays were attracted to the positive side of a magnet and repelled by its negative side.
- Determined that the cathode rays were in fact streams of negatively charged particles (electrons).
- This discovery showed that the atom is divisible.
- Based on his studies, Thomson proposed the "plum pudding" model of the atom:

① Positively charged spherical mass

② Electrons are embedded in the sphere.

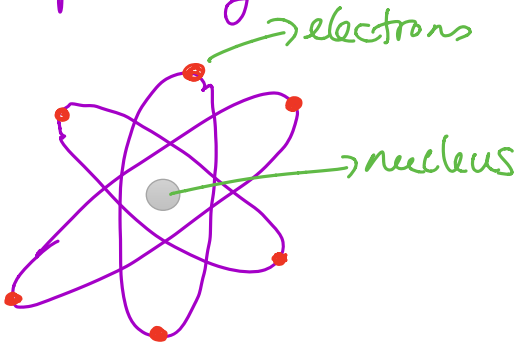


Ernest Rutherford (1910)

- Conducted the famous gold foil experiment with the help of two of his students.
  - Directed alpha (α) particles (positively charged particles) at very thin sheets of gold foil.
  - Most alpha particles travelled through the gold foil without or slightly deviating from their path.
  - Some of the alpha particles were strongly deviated, even to the point of going back to where they were launched.
- From their results, they concluded:
  - Atoms are mostly empty space.
  - Positively charged particles are concentrated in the center of the atom, which Rutherford called the nucleus.

- Based on the findings, Rutherford proposed the following "planetary model" of the atom:

Electrons move in a circular fashion around the nucleus.



- Limitations of Rutherford's atomic model:
  - A nucleus composed only of positive charges would break/fall apart because of the electrostatic forces of repulsion.
  - The model does not explain the total mass of the atom.
    - Was later explained by the discovery of neutrons by Chadwick in 1932.
  - According to scientific law and physics, electrons in motion around the nucleus would lose energy due to radiation causing its radius to decrease, and thus would cause the electrons to spiral in towards nucleus and destroy the atom.

Questions (based on questions on p. 173 of textbook):

1. How did Dalton's atomic theory help explain the laws of conservation of mass? What are some of the shortcomings of Dalton's atomic model?
2. A friend of yours is confused about why Thomson's model of the atom was sometimes called the "plum pudding" model. How would you explain this to your friend? Is there a similar analogy you can use that might be more familiar to your friend?
3. Draw a diagram of what Rutherford and his students expected to happen when they directed alpha particles at the gold foil if the Thomson's model of the atom was correct. What did they observe when they performed their experiment (include a diagram)?
4. How did Rutherford's gold foil experiment support that the atom was mostly empty space? Why did Rutherford conclude that the nucleus was positively charged?
5. Describe the contributions of Dalton, Thomson, and Rutherford to the development of the atomic structure.

Gold foil experiment